INTERACTIONS BETWEEN CATTLE, WHITE-TAILED DEER AND NORTHERN BOBWHITE ON RANGELAND MODIFIED BY PRESCRIBED FIRE

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Task I

Interactions between Cattle, White-tailed Deer and Northern Bobwhite on Rangeland Modified by Prescribed Fire

by

Susan M. Cooper*, M. Keith Owens, and Joseph W. Holloway

Texas AgriLife Research

Texas A&M University System

1619 Garner Field Road

Uvalde, Texas 78801

Phone	830 / 278 9151
Fax	830 / 278 1570
E mails	s-cooper@tamu.edu

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ABSTRACT

Restoration of southern US rangelands to improve habitat for wildlife and livestock often involves large scale shrub reduction programs aimed at increasing the production of more nutritious grasses and forbs. Historically, fire limited the encroachment of woody plants into grasslands, therefore prescribed burns may effective in reducing the dominance of shrubs and stimulating herbaceous growth. We investigated the effects of 3 patch burns of 40 ha each on the distribution of northern bobwhite (*Colinus virginianus*) and white-tailed deer (*Odocoileus virginianus*) on a mixed cattle-wildlife ranch in southern Texas. In this semi-arid area, lack of rainfall after the burns limited regrowth of the vegetation. Prescribed burns had no effect on shrub density and cover. Decreased herbaceous cover after the burns was attributed to the dry conditions and was not an effect of treatment. Burning did not increase herbaceous forage, nesting cover or insect food for wildlife, and quail, deer and cattle showed little selection for the burned areas. Deer and cattle maintained temporal separation, yet on the few occasions the two species did meet deer showed no avoidance response until cattle were within 50 m. Thus, it is unlikely that lack of use of the large burned areas by deer would be due to displacement by cattle. We conclude that prescribed burns should be considered as just one of several range improvement tools available to land managers, and usefulness of this technique on rangeland in drier areas may be limited by environmental and social constraints.

INTRODUCTION

Historically, wildfires suppressed shrub encroachment on rangelands but decades of fire suppression and heavy cattle grazing, in combination with climate change, have allowed the vegetation extensive areas of rangeland to reach a climax state dominated by woody shrubs (Archer at al 1988, Archer 1989, Scifres and Hamilton 1993). Fire as a tool in land management is still under-utilized, and is often perceived as dangerous and difficult to control. Ranch managers and land management agencies may be limited in their ability to use using fire as a management tool by these perceptions. Hunting revenues have become a substantial additive income to traditional cattle ranching in the southern US rangelands and wildlife production is becoming a driving force in rangeland management (Adams et al. 2000, Kuvlesky 2007). Large scale brush reduction programs become more cost effective when habitat is improved for both cattle and wildlife. Mechanical treatments are most common but prescribed burning has proven to be very effective in some areas (Ruthven et al 2000, Armstrong 2005), and is often less costly than mechanical brush removal treatments (Conner 2007). Currently, extensive land treatments are being implemented without a clear knowledge of their long-term value to wildlife and livestock.

White-tailed deer (*Odocoileus virginianus)* and northern bobwhite (*Colinus virginianus*) benefit from any reduction in the abundance of woody plants that shifts the vegetation into an earlier successional stage characterized by increased abundance of herbaceous plants, such as forbs and grasses, which are fast growing, are often more nutritious and less chemically defended than the later successional species (Reynolds et al 1992). Although foliage of woody plants constitutes a high proportion of the diet of white-tailed deer, forbs are the preferred and most

nutritious forage type (Meyer et al 1984, Fulbright and Ortega-S 2006). Forbs are also an excellent source of green food, seeds and insects for bobwhite quail (Hernández and Peterson 2007). When implementing brush reduction treatments for wildlife the interspersion of cleared and brushy areas is important (Kuvlesky et al. 2002, Hillier et al 2005), animals need a matrix of open areas for foraging integrated with shrubby areas for cover. Quail rarely venture more than 200 m from cover (Guthery 1986), and deer also do not venture far from cover.

Cattle are an integral component of rangeland ecology, and may also be used as a tool to benefit wildlife. In productive areas cattle can be used to graze off the overburden of grasses and reducing fuel loads to allow germination of cool season forbs (Bryant et al. 1981; Guthery 1986), but in less productive areas, stocking rates must be low to avoid detriment effects. Cattle may over-graze the clump forming grasses needed by quail for nesting (Lusk et al. 2002), and compete with wildlife for forbs. Several studies indicate that deer may avoid areas where cattle graze (Wallace and Krausman 1987, Cohen et al 1989, Loft et al. 1993, Jenks et al. 1996, Stewart et al 2002.), so cattle may also limit the access of deer to the nutritious new vegetation on burned or mechanically treated pastures. The notion that cattle "scare away" the deer is a source of contention between deer hunters and range managers. In many previous studies of deer-cattle interaction, it was hard to distinguish the response of deer to cattle from the response of deer to the humans tending the cattle. With the advent of GPS satellite telemetry it is now possible to answer this question by tracking the movements of both deer and cattle without any human interference confounding the results.

The aim of this study was to determine the spatio-temporal distribution of white-tailed deer and northern bobwhites in response brush reduction programs by fire (controlled burns) and

to establish whether use of treated areas by deer is likely to be influenced by the presence of cattle.

METHODS

Site Description

The study was conducted on a 6,764 ha ranch, in Uvalde County, Texas, (29° 15' 0.02'' N, 100° 5' 54.01'' W) located in the transition zone between the Edwards Plateau and South Texas Plains ecoregions. Topography of the ranch was primarily gently undulating caliche ridges with thin calcareous soils of low productivity (Stevens and Richmond, 1970). Typical vegetation consisted of mixed thorn shrub community containing guajillo (*Acacia berlandieri*), blackbrush (*Acacia rigidula*), and cenizo (*Leucophyllum frutescens*) shrubs, interdispersed with prickly pear cactus (*Opuntia lindheimer*i). Grass cover was sparse but included Wright's threeawn (*Aristida purpurea*), red grama (*Bouteloua trifida*) and Hall's panicum (*Panicum hallii*). The most abundant forbs were western ragweed (*Ambrosia psilostachya*), one-seeded croton (*Croton monoanthogynous*) and noseburn (*Tragia ramosa*)

Scattered trees of honey mesquite (*Prosopis glandulosa*) and live oak (*Quercus virginiana*) grow on the deeper clay loam soils associated with low lying areas and drainages. These more fertile areas also support a mixed shrub community which includes whitebrush (*Aloysia gratissima*) and Texas persimmon (*Diospyros texana*). The most abundant grasses were common curly-mesquite (*Hilaria belangeri*), buffalo grass (*Buchloe dactyloides*), lovegrass tridens (*Tridens eragrostoides*) and Texas wintergrass (*Stipa leucotricha*). Western ragweed (*Ambrosia psilostachya*), violet ruellia (*Ruellia nudiflora*) and false ragweed (*Parthenium

hysterophorus) were the most common forbs. In all areas a diverse forb cover varies with rainfall pattern and abundance.

Within the ranch, this study focused on a 2,091 ha pasture delineated by an ephemeral river and steep terrain on the southern side and by high fencing on the other 3 sides. The river was not a barrier to animal movements, for most of the year the only surface water was in 2 semi-permanent pools and the water flowed subsurface through the limestone cobbles. In September 2005 a low fence, excluding cattle from the riverbed and adjacent riparian areas was completed, this restricted cattle but not deer to a 1,211 ha pasture. Cattle density within the pasture was reduced to 1 cow-calf unit to 35 ha, managed on a rotational grazing system based on forage availability. This density is considered compatible with bobwhite quail production in South Texas (Hernández et al 2007). Deer density was approximately 1 animal per 10 ha. Quail density was unknown prior to the project but was generally perceived as being low.

The climate was semi-arid with erratic precipitation patterns. Mean annual rainfall was approximately 620 mm, but during this study annual precipitation was above average (883 mm) in 2004 then declined to far below average (180 mm) in 2006. Average annual maximum and minimum temperatures were 35.5°C and 13.7°C, respectively (NOAA).

Land Treatment

Initial project design called for 3 areas totaling 10% of the cattle pasture (6% of the study area) to be burned in summer each year. However, conditions were too wet in summer 2004, and the first time it was possible to burn the first 3 areas was in late September 2005. Drought conditions prevailed in the following year and a state wide burn ban precluded any further prescribed burns for the next 18 months. Therefore only 3 areas of 40 ha each were burned. All

burned areas were in the mixed clay loam and shallow ridge range sites. Due to the scattered spacing of shrubs and low availability of grass for fine fuels, these burns resulted in an interspersion of burned and unburned patches. Treatment areas and ranch infrastructure were mapped during the RISE project using a sub-meter GPS unit (Trimble GeoXT, Sunnyvale, CA), and topographic information was obtained from georeferenced satellite imagery.

Response of Vegetation to Prescribed Burns

We measured woody shrub density, shrub cover, and herbaceous ground cover, in summer, on 6 30 m × 2 m belt vegetation transects inside the eastern and central burn patches and 6 paired control transects outside the burned areas. Transect locations were randomly allocated through use of the Random Sampling Tools Extension in ArcView 3.2. We divided plants into preferred and non-preferred deer forage categories based on information from Taylor et al. (1997) and local expertise. To measure shrub density we counted every individual stem with its own root system within the transect, then averaged the data from the 3 transects for each site and treatment. To measure brush cover we used the line-intercept method (Bonham 1989), and measured the length that a branch or stem intercepted the vertical axis of the transect line. We then calculated the percent cover of vegetation on each site and averaged the 3 transects for each site. To measure percent cover of herbaceous ground cover e.g., grasses and forbs, we placed 5 0.5 m^2 quadrats along each transect. The first quadrat was placed randomly between 0 and 5 m, then the remaining 4 quadrats were placed every 5 m. We situated quadrats so that they would not include any large woody shrub stems because grass and forbs were the main concern for these samples. We compared shrub density and cover between treatment, year, and treatment × year interaction using SAS PROC GLM (General Linear Model), and used t-test to assess

whether considered categories of vegetation cover altered after the burns and accepted differences at $\alpha = 0.05$.

Abundance and Distribution of Northern Bobwhites

Northern bobwhite quail density and distribution was monitored through spring call counts from 6 fixed survey points. Assuming an audible calling radius of 600 m (DeMaso et al. 1992), 113 ha was surveyed at each listening post. Call counts are not indices to absolute abundance, but have been used to quantify population change in response to brush management and land use at landscape scales (Roseberry 1982, Hansen and Guthery 2001). We considered call counts to be a more suitable comparative index of quail abundance in brush dominated systems than visual counts from road transects because road counts tend to be biased towards greater visibility of quail on more open areas. An auditory survey also allowed us to survey a much larger area than could be achieved from road counts. During May–June we began surveys at sunrise and continued for 1.5 hours. At each point, within a 5 minute period number of roosters heard was recorded, together with number of calls/bird and estimated the direction and distance of calling birds from the observer. Counts were replicated on 3 separate mornings. We plotted the estimated location of each bird heard to assess proportion of birds calling from treated and control areas.

Cover is critical for quail nesting success (Guthery 1986), therefore we assessed the availability of suitable nesting clumps of vegetation in burned and unburned areas in spring just prior to the nesting season. We counted nest clumps along 6 permanent transects measuring 300 m long and 2 m wide (Slater et al 2001), 3 were situated within the burn area and 3 were outside the treated areas in the same range type. Nest clumps were defined as grass tufts > 30 cm in

diameter or cactus > 60 cm wide (Lehman 1984, Hernández et al 2003). Quail suffer high rates of nest predation (Hernández et al 2007) especially when nesting cover is sparse. In summer, we placed 15 artificial nests along each nest transect, situating these nests at 10 m intervals in the best natural cover available within the belt transect. We monitored the fate of these 90 nests daily for up to 42 days. Egg shell breakage patterns provided a rough guide to identifying likely predators, along with 1 automated camera placed on each transect line for more accurate identification (Cooper and Ginnett 2000).

Once chicks hatch, abundant arthropod food is important to their early survival (Hernández and Peterson 2007). We sampled arthropod numbers and biomass in summer by sweep netting the vegetation (25 sweeps in a random direction) at 10 randomly chosen points within 25 x 25 m grids located 100 m inside and outside each burned area. We identified arthropods were identified to order, and counted, dried and weighed them.

Within the same grids at 15 random points, we quantified visual obstruction of cover for quail with a robel pole (Robel et al. 1970). At each sampling point, from each of the 4 cardinal directions we recorded the lowest 0.5 dm strata visible from 4 m away at a height of 1 m.

Distribution of White-tailed Deer

We examined the spatial distribution of deer in 5 trials each lasting 30 days. Trial 1 August 2005, was prior to the prescribed burn, which was conducted on late September 2005. This trial was in summer of a high rainfall year with ample forage. Trial 2 in November 2005 was 1 month after the burn, rain a week after the burn had allowed a little regrowth of grasses. Trial 3 in March 2006 was scheduled for spring green up although poor spring rainfall limited plant growth. Trial 4 in July 2006 was in summer during drought conditions. In trial 5 in October 2006 a year after the burns conditions were still very dry.

We assessed spatial distribution of animals through use of GPS collars on 6 deer (Lotek GPS 3300S with drop-off latch, Lotek Wireless, Inc., Newmarket, Ontario, Canada). GPS locations collected by these collars are accurate to within 5 m after post-processing differential correction (Lotek 2006). Animal handling was in accordance with Texas A&M University Laboratory Animal Care and Use Committee Animal Use Protocol 2004-49. Using professional contractors, we captured 1 buck and 1 doe by helicopter drop-net in each of the east, central and west sections of the cattle pasture. We ear tagged each deer to avoid using the same animals in subsequent trials, and fitted a GPS collar scheduled record 1 locations per hour for 30 days, with an inclusive period recording locations 5 min intervals for 12 days.

We used the 1-hour interval to assess animal distributions, this interval provides adequate time for the deer to move to any location within their annual home range thus limiting spatial autocorrelation of data points (Frair et al. 2004). The annual home ranges of white-tailed deer on this ranch are about 700 ha in extent (Cooper et al. 2006). We used the 5 minute data to determine interactions between deer and cattle and for more detailed examination of animal locations during peak feeding times.

Spatially and temporally explicit animal distribution patterns, treatment patch occupancy, and responses of deer to the presence of cattle were derived from GPS data using the ArcView 3.2 and 9.1 (ESRI, Redlands, CA). We calculated monthly home range sizes using the kernel home range estimators which include utilization distribution probabilities (Worton 1989). To determine whether deer used burned areas in proportion to their availability in the study area we calculated the number and proportion of position fixes for each deer that fell within the burned areas. We used SAS™ PROC CATMOD (Categorical Data Modeling) to examine differences between the responses of bucks and does to the burns at different times after the burns. We used Chi-squared

($\chi 2$) tests to compare this with the observed proportion of relocations of animals in the burns with the expected proportion if the animal used the burned and unburned areas in proportion to their availability within the study area (i.e., 6% of deer relocation fixes would fall within the burned areas).

Total daily distribution of deer does not show whether animals are using particular areas for feeding, resting or other activities. Deer are crepuscular with circadian activity peaks around dawn and dusk (Montgomery 1963; Coulombe et al. 2006). We used activity sensors within the GPS collars to identify the peak activity times of deer, then used the GPS locations collected at 5-minute intervals to provide accurate, fine-scale information of distribution of deer during the 4 hours of maximum activity when deer were most likely to be feeding. Again we used the Chi-squared test to determine whether or not deer were selectively distributed in the burned areas during their most active periods.

Interaction between Deer and Cattle

We fitted GPS collars (Lotek GPS 3300LR) on 9 cows (Bos taurus Angus-Bonsmara crosses), and programmed them to collect position fixes every 5 minutes for 12 days in synchrony with the deer collars. Treating the cattle as a herd, we assessed cattle selection for burned areas and used Chi-squared ($\chi 2$) tests to compare the observed proportion of relocations of cattle in the burns with the extent of burns within the cattle pasture (10%).

We imported collar data from each animal into an ArcView GIS datatabase and calculated the coordinate pairs (X, Y) for all locations for data from all animals synchronized at 5 min intervals. To avoid directional or distance autocorrelation we thinned the data at 1 hour intervals (Perotto and Cooper, unpublished data). We calculated euclidean distance between each deer and cow (bucks and cows, does and cows separately) and summarized distances to estimate the mean

and standard error for all occurrences for every hour within the trial period. To investigate close contacts between deer and cattle, we used tracking analyst to quantify the number of instances within the entire dataset when a collared deer and cow came within 100 m of each other. The closest distance between the two animals was measured and the movement response of the deer to the cow was recorded as avoidance or non-avoidance.

RESULTS

Response of Vegetation to Prescribed Burns

No significant change in vegetative production could be attributed to the effects of the prescribed burns (Table 1) Prescribed fire did not change shrub density, of either shrubs eaten by deer ($F_{3,4} = 2.39$, $P = 0.210$) or non-preferred shrubs ($F_{3,4} = 0.91$, $P = 0.511$). Similarly differences in shrub cover could not be attributed to the burns. ($F_{3,4} = 0.33$, $P = 0.804$). In the summer after the burns the herbaceous cover had declined on both burned and control sites and proportion of bare ground had increased. This indicates that changes in vegetative cover were due to less favorable growing conditions in the year after the burn, rather than treatment effect. The most significant changes were a decrease in forbs on the burned areas ($t_{10} = 10.27$, $P \leq 0.001$) and a decrease in grass ($t_{10} = 2.95$, $P = 0.015$) and increase in bare ground ($t_{10} = 4.86$, $P \leq 0.001$) on the control sites.

Cover for animals was mainly provided by perennial shrubs, and because burning had little effect on shrub density or cover there was also little effect on visual obstruction values. Visual obstruction was 9.40 ± 1.20 in the pre-treatment areas and 11.55 ± 2.00 in the control areas. After burning visual obstruction was 11.34 ± 1.07 in the burns and 11.29 ± 2.03 in the control areas. These minor differences are not significant.

Abundance and Distribution of Northern Bobwhites in Response to Prescribed Burns

Abundance of northern bobwhites was low throughout the study. Prior to land treatment an average of 1 quail was seen per 10 km of road driven and 1.4 bobwhite roosters were heard per survey site (Table 2). Implementation of the burns in September 2005 coincided with a change in weather patterns towards drought. In the summer after the prescribed burns, quail numbers were extremely low. No quail were seen on the roads from May through July, and only 1 rooster was heard for every 6 auditory survey points, no quail were heard calling from the burned areas. In 2007 road counts returned to 1 quail sighted per 10 km. The number of calling roosters did not increase but the few birds calling appeared to be mainly in the burned areas,

Availability of nest sites for bobwhites

Nest cover for quail was very low and was not improved in the short term by prescribed burning. In the 3 areas selected for treatment, mean nest clump availability was 18.8 ± SE 2.2 cactus clumps / ha, and only 2 suitable grass clumps were found. After the burns the number of cactus nesting clumps was unchanged. No grass nest sites were available in 2006 either on the burned areas or the control areas, but in the second year one of the two grass nest clumps had resprouted.

Nest Predation

Predation rates on artificial nests were severe, no nests remained undetected by predators for more than 3 days, there were no effects of year and treatment. Automated cameras (128 photographs) showed that predators were similar in all years. Raccoons and skunks were the main predators taking 51.6% and 24.2% of nests respectively. Avian predators took 9.4% of nests and other mammals (armadillo, feral hog, bobcat) accounted for the remaining nests. Patterns of egg breakage also implicate raccoons as the major nest predators, at 46.7% of nests the egg shells

were broken in half or in large pieces which is characteristic of raccoon predation. At the other nests 20.4% eggs were fragmented, 4.6% had a hole nibbled in them and 28.3% were never found.

Arthropod production

Biomass of arthropods was similar in control and pretreatment areas (Table 3). In 2006 after the burn, biomass decreased at all sites but the decrease was strongest in the burned areas (t_4=4.997, p<0.01), in the second year this difference was no longer evident. Number and biomass of arthropods caught declined from 2004 to 2006 and rebounded in 2007. Throughout the study the most abundant orders were Arachnids (Spiders), Homoptera (Aphids), Hemiptera (Bugs) and Orthoptera (Grasshoppers).

Use of Burned Areas by White-tailed Deer

The mean range (95% kernel) of a buck during a 1 month trial was 234 ± 36 ha (max 504 ha), does tended to use smaller areas 67 ± 11 ha (max 124 ha). Thus area use by bucks was substantially greater than that of does (t_{20} = 4.96, P < 0.001). Deer concentrated 50% of their distribution within a core area covering about 10% of their monthly range (bucks 9.86 %, does 11.05%). There were significant differences both in use of burned areas between trials (χ^2_1 = 379.13, P ≤ 0.001) and between genders (χ^2_1 = 76.37, P ≤ 0.001).

Prior to the burns, the distribution of 2 bucks and 1 doe overlapped the intended burn sites (Fig. 1), but intensity of use was low, and the core areas of these deer were not within the pre-treatment areas. The proportion of relocations of deer within the pre-treatment areas was less than expected for bucks (χ^2_1 = 39.08, P ≤ 0.001), and in similar proportion to availability for does (χ^2_1 = 1.12, P = 0.290).

In the fall, 1 to 2 months after the burn, deer use of burned areas increased, 5 of the 6 deer had some proportion of their distribution within the burned areas. None of the core use areas fell within the burns, however, both bucks and does were relocated within the burns more often than expected ($\chi^2_1 = 71.50$, $P \leq 0.001$ and $\chi^2_1 = 22.35$, $P \leq 0.001$, respectively).

Use of burned areas by deer declined by spring, 2 bucks and 1 doe were distributed within the burned areas but none of the core areas were in the burned areas. Relocation records indicate that bucks used the burns less than expected ($\chi^2_1 = 6.93$, $P = 0.009$), and does used the burned patches in similar proportion to their availability ($\chi^2_1 = 2.33$, $P = 0.127$).

In summer, almost a year after the burns, the range of one buck encompassed an entire burn patch, and overlapped a small part of two other burned areas. A small proportion of the core area of this buck was in a burn. The other bucks, however, did not select the burned areas and overall relocation records of bucks indicated that they used burned patches as available ($\chi^2_1 = 2.35$, $P = 0.125$). In this trial does were relocated in the burned areas less than expected ($\chi^2_1 = 47.10$, $P \leq 0.001$).

In the fifth trial 1 year after the burn, the deer were in rut and damage caused to the antennae of the collars resulted in poor data collection for bucks, but overall bucks tended to avoid the burned patches ($\chi^2_1 = 18.02$, $P \leq 0.001$). The monthly range and part of the core areas of 2 does overlapped the burn areas, thus overall does used burned areas in greater proportion than their availability ($\chi^2_1 = 538.88$, $P \leq 0.001$).

Unlike deer cattle did not select the burned areas in the fall, instead they used the burned areas in greater proportion than availability in spring (19%, $\chi^2_1 = 8.05$, $P \leq 0.01$), in other seasons use was in proportion to availability.

Deer Use of Burns at Dawn and Dusk

Deer were not preferentially distributed on the burned areas during their peak activity times when they are most likely to be feeding. Prior to burning bucks used treatment areas proportionally less than availability ($\chi^2_1 = 12.45$, $P \leq 0.001$) and does used the areas in proportion to availability. In the fall, after the burns, this pattern reversed, bucks used the burns in proportion to availability while does were relocated in the burns less than expected ($\chi^2_1 = 7.89$, $P \leq 0.01$). In March and July all deer used the areas proportionally less than their availability, (March $\chi^2_1 = 38.28$, $P \leq 0.01$, July $\chi^2_1 = 26.42$, $P \leq 0.001$), thus showed selection against using the burned areas during their foraging times.

Interactions between Deer and Cattle

There was very little close interaction between white-tailed deer and cattle, collared individuals of the 2 species consistently stayed about 2 km apart at any point in time (1909 ± 210 m). There was no difference in the distance bucks and does to cattle. Slight variations in distance occurred during the daily cycle but the magnitude was only about 300 m which is minimal compared to the overall distance between the species.

On a few occasions deer and cattle came in close contact with each other, there were 121 records of collared cattle and deer coming within 100 m of each other. There was no evidence that moving deer changed course to avoid cattle, animals usually passed at 53 ± 2 m distance but were twice deer were recorded within 10 m of cattle. On 30 occasions cattle approached a stationary deer. Responses of the deer were very variable but in general distances at which deer tended to move away or stay when a cow passed by were significantly different ($t_{28} = 2.113$, $P < 0.05$), deer tended to be displaced by cattle approaching within 46 ± 5 m (n = 15), but tolerated cattle at 64 ± 7 m (n = 15) distance.

DISCUSSION

Use of prescribed fire to improve shrub-dominated rangelands for wildlife and livestock has met with varying results. When applied successfully, fire can reduce woody plant cover, allowing an increased proportion of sunlight and rainfall reach the ground to stimulate herbaceous production (Owens et al. 2002), thus improving nutrition for wildlife (Bozzo et al. 1992).

The effectiveness of fire depends on frequency and intensity of burns and weather conditions after the burn. In the more mesic areas of East Texas prescribed burns have been successful in stimulating forage production for wildlife (Box and White 1969; Landers and Mueller 1992). In Central Texas on the Edwards Plateau, a long term prescribed burning policy reportedly reduced brush cover and increased forb production and diversity (Armstrong 2005). However, in more xeric regions, as described in this study, prescribed burning tends to be less effective (Ruthven et al. 2000; Owens et al. 2002; Valone et al. 2002). In semi-arid rangeland, fuel loads are often insufficient to support the intense fires needed to reduce shrub dominance, thus the effect of prescribed fire on vegetation cover and composition is limited (Frost and Robertson 1987, Owens et al. 2002). In these areas vegetation growth is dependant upon the erratic rainfall. Timely rains can produce a flush of annuals and regrowth vegetation, but there is always a risk of minimal response due to dry conditions.

In this study, even though the previous year had above average rainfall and had good vegetative growth, the fine fuel load between shrubs was sparse and fire did not carry well. The treated areas became a mosaic of burned and unburned areas without large changes in the structure and composition of the woody component of the vegetation. Rainfall a week after the burns created a brief flush of grass growth in the fall, but in spring and throughout the following

year below average rainfall limited vegetation growth. No measurable difference in shrub density or cover of woody plants, grasses or forbs could be attributed to the prescribed burns.

Abundance and Distribution of Northern Bobwhites

Quail numbers on the ranch were low, the study area was predominantly a mixture of clay loam ecological sites which are favored by quail, and shallow ridge and stony ridge sites which typically have few quail. On nearby ranches managed primarily for quail, mean number of quail per count circle was 4 on clay-loam sites and 1 on shallow ridge sites. (Cooper et al. submitted). Quail numbers prior to the burn were 1.4 per survey site or 1 quail seen for every 10 km driven. After the burns number of quail decreased, but this is directly attributable to drought, which appears to depress breeding behavior (Wood et al. 1986) and associated calling in bobwhites.

Vegetation conditions on the ranch were unsuitable for bobwhites. Shrub cover was thick, with visual obstruction values around 10. Grass cover, particularly clump grasses suitable for nesting, was sparse to non-existent. The only nesting cover available to the quail was clumps of prickly pear cactus (Hernández et al. 2003). The low intensity burns singed but did not destroy the cactus clumps, no increase in grass production occurred. Recommended nest clump density for bobwhite management is over 600 clumps/ha (Guthery 1986), in this study the quail only had <20 available nest clumps/ha. The vulnerability of these nests to predators was amply demonstrated by the fact that none of the 90 artificial nests put out each year lasted more than 3 days before being discovered by a predator. Since fire had no effect on vegetative cover or nest clump availability, it was not a factor influencing rates of nest predation. Although mammalian predators predominated, due to poor nesting cover, avian predators which hunt by sight not smell, were able to take 10% of the nests. It should be noted that artificial nests are merely an indicator of predation pressure not an exact measure, since they are not camouflaged or protected by the

hen, never the less depredation rates were still extremely high. Chicks and laying hens require high protein arthropod food (Hernández and Peterson. 2007). Arthropod biomass measured in this study was very low compared to that in north Texas (D. Ransom pers comm.). It is to be expected that arthropod biomass would increase in response to the production of tender regrowth vegetation following a burn. Since there was no vegetative response to prescribed burning, there was also no increase in arthropod production. The drought mediated decline in arthropod biomass in 2006 was a little more severe in the burned areas than control areas. Thus, while prescribed fire may be expected to improve habitat for quail by greater production of herbaceous plants for cover and food production, this does not always happen (Koerth et al. 1986), especially when precipitation patterns are not favorable. On the other hand while not helping quail production, the burns did not cause harm, no declines in quail numbers were attributed to the burns. It is possible that repeated treatment would be required to affect adequate vegetation response to influence quail survival.

Distribution of White-tailed Deer relative to Prescribed Burns

White-tailed deer, like the quail, were minimally impacted by the burns. Prior to the burns the deer did not have any particular attraction to the areas to be treated. In the fall following the burn, use of treated areas by deer increased. The deer may have been attracted to the new growth of grass. Browsers do not typically eat grass but they can use the new growth while it is still young and comparatively rich in nutrients and low in fiber. Deer in coastal south Texas may obtain 22% of their winter diet from grasses (Chamrad and Box 1968). Yet, the new grass may not have been the factor attracting the deer to the burns, deer were not preferentially located in the burns at dawn and dusk, which are their primary feeding times (Montgomery 1963), in fact they tended to select against the burned areas during this time. Drought conditions prevailed in South

Texas throughout 2006, this meant that herbaceous vegetation had little chance to continue the initial flush of growth seen in the previous fall. In the following spring and summer, the deer showed no attraction to the burned areas, probably because there was little difference in vegetation inside and outside the burned areas to influence their distribution. Passage of time from the burn may also be a factor in this pattern, because even when fires do stimulate regrowth the effect tends to be transient because the contrast in nutritional quality of vegetation on and off the burns soon declines (Wallace and Crosthwaite 2005).

Deer and cattle showed very little interspecific interaction. Collared deer and cattle were consistently distributed about 2 km apart, this distance is exaggerated by small sample size but still shows a trend for deer and cattle to be temporally separated when in shared habitats. Although there was fresh regrowth of grass on the burns 1-2 months after treatment, cattle, unlike deer, did not congregate on the burns at this time. Cattle only favored the burned areas in spring, deer did not select the burns at this time. Deer use of burns may be influenced by avoidance of cattle, but on the few occasions deer and cattle did come close to each other the deer did not move away until the cattle were within 50 m. This is similar to the to 75 m distance between cattle and mule deer reported by Loft et al. (1993). Thus in a 40 ha burn it is unlikely that lack of selection of burned areas by deer can be due to their being displaced by cattle.

Conclusion

Management implications of this study are that the use of one time prescribed burns to improve habitat for livestock and wildlife in semi-arid rangelands will not be successful if environmental conditions are not suitable to produce adequate fine fuels prior to the burn and regrowth of the vegetation after the burn. In this environment, prescribed burns may be better utilized as part of an Integrated Brush Management System (IBMS) (Scifres et al. 1983; Scifres et

al. 1985; Hamilton et al. 2004) to achieve rangeland restoration goals. Fire may best be used as a maintenance treatment after mechanical shrub reduction (Hernández et al. 2007), or in conjunction with mechanical treatments which knock down woody vegetation to increase the fuel load (Ruthven et al. 2005). There may also be social constraints on use of fire, in this study a statewide burn ban to protect suburban property was implemented at the time when prescribed fire would probably be most effective on rangeland. Thus the use of prescribed burning as a management tool on semi-arid rangeland may not always be successful or applicable to certain situations due to climatic and social constraints. Prescribed fire should be considered as just one of several range improvement tools available to land managers in an integrated brush management program.

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FIGURE LEGENDS

Figure 1. Fixed-kernel density estimates of white-tailed deer distribution relative to prescribed burns. August 2005 (pre-burn) and 3 subsequent trials in which 3 bucks and 3 does were fitted with GPS collars for 30 days. 95% kernel ranges in shades of grey with 50% core use areas in black, burned areas denoted by hatch shading.

TABLE CAPTIONS

Table 1. Mean cover (%) with SE of vegetation and bare ground in treatment and control plots before and after prescribed burning.

Table 2. Abundance and distribution of northern bobwhites before and after implementation of 3 prescribed burns covering 10% of the study area, and annual rainfall 12 months prior to the surveys.

Table 3. Mean dry weight and number of arthropods in summer before and after prescribed burning, 25 sweeps of a net on 3 treatment and 3 control sites.

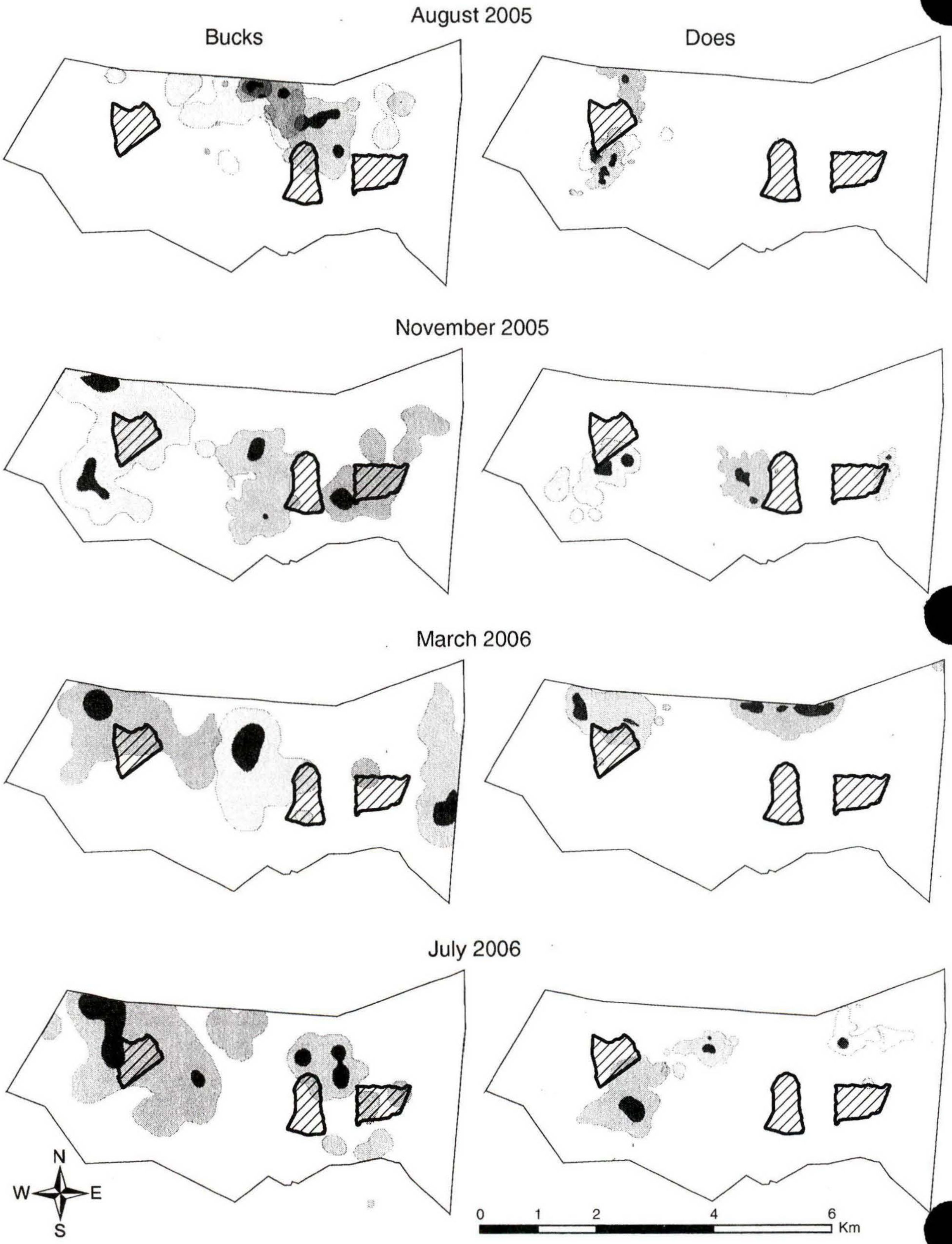
August 2005
Bucks
Does
November 2005
March 2006
July 2006
N
W
E
S
0
1
2
4
6
Km

Table 1. Mean cover (%) with SE of vegetation and bare ground in treatment and control plots before and after prescribed burning.

Date	Shrubs		Forbs		Grass		Litter		Bare ground	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
2005 Preburn	30.29	3.60	19.40	0.33	23.73	4.87	16.53	4.67	38.03	10.10
2005 Control	33.69	6.56	15.03	1.63	31.87	4.20	14.20	4.73	36.70	1.63
2006 Burned	35.44	7.04	8.10	0.77	13.23	3.30	21.63	6.63	51.43	1.17
2006 Control	35.96	7.80	7.13	2.27	16.23	1.10	16.30	2.17	57.43	2.63

Table 2. Abundance and distribution of northern bobwhites before and after implementation of 3 prescribed burns covering 10% of the study area, and annual rainfall 12 months prior to the surveys.

Count Dates	Road count Quail/ km			Call count Birds/site			% quail calling in burn	Rainfall (cm) prev. 12 mo (ave 60cm/yr)
	Mean	SE	days	Mean	SE	n		
2004 preburn	0.11	0.02	30	1.94	0.50	6	21	87.4
2005 preburn	0.11	0.09	23	0.78	0.22	6	67	73.4
2006 postburn	0.00	0.00	28	0.17	0.07	6	0	27.3
2007 postburn	0.10	0.10	10	0.17	0.07	6	88	41.4

Table 3. Mean dry weight and number of arthropods in summer before and after prescribed burning, 25 sweeps of a net on 3 treatment and 3 control sites.

Count Dates	Weight (g) Burn		Weight (g) Control		Number Burn		Number Control	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
2004 preburn	0.081	0.008	0.065	0.022	19.8	0.7	11.6	0.3
2005 preburn	0.028	0.014	0.014	0.003	8.2	1.9	7.6	2.8
2006 postburn	0.006	0.001	0.011	0.003	2.0	1.7	2.3	0.4
2007 postburn	0.272	0.272	0.011	0.003	5.8	2.0	8.3	2.5

PRODUCTS AND ACCOMPLISHMENTS

So far this project has generated 2 peer-reviewed articles, 1 Masters thesis, 1 international presentation, and 8 other scientific presentations. Posters were also displayed at the Department of Wildlife and Fisheries Sciences in College Station, Texas Agricultural Research and Extension Center in Uvalde and on the center website. Further publications are planned in conjunction with the RISE project funded by Joe Skeen Institute for Rangeland Restoration and in part by funds provided by the Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture.

1. Meek, M.G., S.M. Cooper, M.K. Owens, R.M. Cooper, and A.L. Wappel. (Submitted) Distribution of white-tailed deer in response to prescribed burns on rangeland Journal of Arid Environments.
2. Cooper, S. M. H. L. Perotto, M. G. Meek, M. Figueroa-Pagán and M. K. Owens. (Submitted) Multiple scale analysis of interaction between white-tailed deer and cattle in a semi-arid grazing system. Agriculture, Ecosystems and Environment
3. Meek, M.G. 2007 Spatio-temporal distribution of white-tailed deer relative to prescribed burns on rangeland. M.S. Thesis. Texas A&M University, College Station, TX.
4. Meek, M.G., S.M. Cooper, M.K. Owens, and A.L. Wappel. 2006. Spatio-temporal distribution of white-tailed deer relative to prescribed burns on rangeland in south Texas, USA. 6th International Deer Biology Congress, Prague, Czech Republic. Aug 7-11, 2006.

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12. Meek, M.G., S.M. Cooper, M.K. Owens, and R.R. Lopez. 2006. Spatial and temporal distribution of white-tailed deer relative to prescribed burns on rangeland. 7th Annual